WATERWAY IMPROVEMENTS

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By virtue of the increased tonnage and draught of vessels, the constant deterioration of river channels and harbor bars has led to the expenditure of enormous sums of money in efforts to maintain the world's maritime traffic through such channels.

Attempts have been made to solve this complex problem of deterioration by the use of jetties in pairs, aided by dredging, and great progress has been made in the efficiency of hydraulic dredges. Mechanical appliances do not modify, however, the forces which mould the beds of the channels in plastic material and can never serve to automatically maintain the depths they tentatively secure.

For the purpose of ensuring greater safety, speed, and economy in the maritime interchange of trade, the expenditures by all nations will aggregate more than $100,000,000 annually. Yet the possibility of preventing such expenditures by utilizing the energy of the maritime forces themselves, instead of endeavoring to combat those forces, does not seem to have been realized until within the last few years, when the utility of such a system has been fully demonstrated, even under exceptionally adverse conditions.

Prior to the improvement of the South Pass in 1879 by two curved jetties, the ruling depths of the Gulf of Mexico at the inlets were from 3 to 12 feet, and large sums of money had been expended in efforts to obtain deeper water, but with little effect. At Galveston, however, after a lapse of some thirty years and an expenditure of over $10,000,000, a tortuous channel of more than 30 feet has been provided, though the bar has advanced over three miles and constant dredging is required to maintain the depths.

At Liverpool, England, it was estimated that the removal of 9,000,000 cubic yards of material would suffice to secure a 30-foot channel to the port.

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[1] Abstract of paper presented at the meeting of the Mechanical and Engineering Section held Thursday, February 8, 1912.

Since 1890, however, more than 121,000,000 tons have been dredged and the depth resulting from it was, in 1908, 28 feet.

In sedimentary streams, jetties merely serve to temporarily extend the banks across the bars and to deposit the silt beyond, in the path of navigation. Thus, the delta of the Mississippi deposits 440,000,000 cubic yards annually, of which more than 102,000,000 cubic yards traverse the Southwest Pass, which is being improved by jetties and dredging. The bar is now over half a mile beyond the ends of the jetties.

Problems such as the above require for their solution a consideration of all the forces and their results, as recorded by the physical forms which they create.

Before the Civil War it was the policy of the Government to aid the States and localities in the conduct of public works on river and harbor improvements. The total expenditures made for that purpose from the National Treasury were less than $15,000,000. Since the Government assumed control of the rivers and harbors, however, it has expended to date about $600,000,000 in efforts to meet the demand for deeper channels. The average yearly appropriations made for this purpose during the last decade are less than $25,000,000, and the commercial interests are demanding double this amount to meet the requirements of trade. The Administration is committed to the policy of completing the existing approved projects, aggregating more than $300,000,000, before any new obligations are assumed.

In making analyses of the several methods of improvements adopted, due consideration must be given to the local physical conditions of tides, currents, winds, waves, and fluvial waters at the mouths of sediment-bearing streams. The littoral drifts, character of material, and rates of movements of purely tidal inlets must also be considered.

The official reports of the Government Engineers, the United States Coast Survey, and other publications furnish data on the methods adopted in the following cases of some of the principal harbor and river entrances along the alluvial seaboard of the United States:

THE DELAWARE RIVER.

For a generation efforts have been made to deepen this river, first to 26, then to 30, and now to 35 feet.

The present project for a 35-foot channel contemplates the use of dikes. The estimated cost of the project is $10,920,000, with $300,000 for its maintenance. The time required to complete it is six years.

Since 1836 there has been expended a total of $10,876,002.18, and the depth as reported is about 28 feet at mean low water. The 26-foot channel project was inaugurated in 1885, and in 1899 was merged before its completion into the 30-foot project, which is now embodied in the present 35-foot plan.

Since 1870 there have been many changes of officers in charge of these improvements and of Boards of Engineers reporting on modifications. The plans have been changed from the prohibition of depositing dredged material in the bed of the stream to the construction of dikes, with a return to dumping behind islands or in artificial enclosures, and again to partial dams connecting natural islands with the adjacent shore. The effect has been to throttle the tides and in some instances, where the water is excessively deep, to make it still deeper, with a consequent shallowing of the resultant shoals. The dikes have been restrained because of encroachment on the riparian rights of the adjacent States, and are now located so as not to act as training walls to maintain the channels from which they are too remote or placed nearly at right angles, greatly reducing the normal cross-section.

THE CHARLESTON ENTRANCE.

In 1878 it was proposed to secure a 21-foot channel over the outer bar of this entrance by two low-tide and submerged jetties at a cost of $3,000,000.

This was modified ten years later, when it was projected to raise the jetties and extend their length at a cost of $4,380,500.

In 1899 another modification was made to procure a 26-foot channel by building larger dredges. In 1910 again, with still more powerful dredges, a 28-foot channel was aimed at, this to cost $371,616.88 additional, with $40,000 for maintenance.

The total cost to June 30, 1911, was $4,783,265, and a good 26-foot channel was reported. Tide, 5.2 feet. The improvement has, however, had no effect on freight rates, although the insurance has been slightly reduced. A project for further enlargement is pending. The three dredges, when working, during the year removed 1,212,722 cubic yards, bin measure, but the solid

removed was apparently much less and the cut is filling from the north side. The average cost per yard was 10.89 cents.

THE ST. JOHN'S BAR.

To obtain a navigable channel of 15 feet from Jacksonville, Fla., to the sea, a distance of 27.5 miles, it was estimated, in 1879, that two convergent low-tide jetties, supplemented by dredging, would be required and that the cost would exceed $1,000,000. The project, when carried out, resulted in a 13-foot channel at a cost of $1,417,000.

Modifications were made in 1896 and again in 1903 to secure a 24-foot channel, by raising the jetties and by dredging, at a cost of $2,176,750. The work was nearly completed and $3,017,890 had been expended, when a new project was adopted in 1910 for a 30-foot channel, at an estimated cost of $2,852,000.

About 4 per cent. of this latter modification is completed, and the maximum available draft is 22½ feet.

CUMBERLAND SOUND, GEORGIA.

The bar in this sound carried originally from 11 to 12.5 feet of water at low tide and was very unstable, drifting through a range of 1½ miles. A proposal was consequently made in 1879 to improve it by two low jetties, 3,900 feet apart, which were expected to give a 19-foot channel by dredging at a cost of $2,071,023. There was expended under this project $932,500.

In 1891 a Board of Engineers recommended the raising of the south jetty to high water throughout, in case the low jetties failed to secure sufficient depths. The plan was modified by Captain Carter in 1895 for two rip-rap jetties extending to 30 feet of water and estimated to cost $2,350,000. Captain Carter's plan was approved.

The reported depth in 1897 was but 13 feet, and the channel crossed the south jetty about 7,000 feet from its initial end.

To enable vessels to enter the port of Fernandina, a portion of the south jetty was removed and an emergency appropriation of $500,000 was passed by Congress to relieve the port from closure.

On the building up of the outer end of the north jetty a channel was soon scoured out under its lee by the natural action

of the currents, and this has since been deepened by dredging, so that the controlling depths last year were 24.5 feet.

In this connection it should be recorded that on October 8, 1890, or about a year after the receipt by him of the "Physical Phenomena of Harbor Entrances," Captain Carter recommended a change of plan in the location of the jetties and the abandonment of the south jetty, with the substitution of a concave outer jetty on the north side of the channel. He estimated that this plan would save $1,096,417. Report of 1901, page 1600, gives the opinion of the Board of Engineers on this plan, however, which is as follows:

"It does not think that a single jetty on the north side of the channel curving gently to the south would secure the deep water needed, but that two jetties are necessary. . . . The idea that a curved channel conforms to the natural requirements of the site and opposes the action of the natural forces less than any other is believed to be fallacious."

THE MOUTH OF THE MISSISSIPPI.

In 1803 Louisiana was purchased by the United States, to secure control of the outlet to the Gulf, and fifty years later the Government began to rake and dredge the bars in efforts to obtain a channel of 18 feet instead of from 9 to 12. Three hundred and thirty thousand dollars was appropriated in 1856 for the purpose of building jetties at the Southwest Pass and stirring up the bottom, but the channel was only maintained so long as the stirring was continued, which was only for one year. By 1870 a powerful dredge was built and used to stir up the bottom, throwing the material into the current, but it did not succeed in maintaining a channel, so that in 1871 the proposition was made to dig a canal at Fort St. Philip, to cost $10,273,000, and secure a passage 25 feet deep by locks. This was met by a proposal by James B. Eads to construct two jetties and obtain 28 feet by dredging at a cost of $10,000,000. Captain Eads's plan was submitted in 1874. In 1875 a Board of United States Engineers reported a project for two straight jetties, to be supplemented by stirring or dredging, to secure a 25-foot channel, and to cost, if at the South Pass, $7,942,110, and if at the Southwest Pass, $16,053,124. The Chief of Engineers declined to approve this

project, and Captain Eads then proposed to open a 30-foot channel at Southwest Pass for $8,000,000 and to maintain it for 20 years at a cost of $150,000. Congress gave him the South Pass work in March, 1875, and in July, 1879, he had secured a channel 200 feet wide at the 26-foot depth, with a maximum of 30 feet, under his contract for $5,250,000.

Thus, 76 years after the purchase, the river was opened for deep-draught vessels by a channel supposed to be adequate for all time. It was not long, however, before the commerce demanded a greater channel, and in January, 1899, a new Board estimated on two parallel straight jetties to open the Southwest Pass at a cost of $13,000,000 for construction and $390,000 annually for maintenance.

At the request of a member of the River and Harbor Committee, the writer prepared a project for a 35-foot channel and offered to open the pass at a cost of $6,000,000, with $100,000 for maintenance. The plan was referred to a Board of Engineers, which modified it, suggesting what was known as the "bottle-shaped" jetties, to be accompanied by dredging, at the low cost of 4 cents per yard; total cost, $6,000,000. As these two jetties, at distances varying from 3,000 to 7,000 feet apart, constituted a trap for sediment, the project was again modified, though not improved, and a contract made for its construction in 1903, after the writer had demonstrated the probable results of the modifications.

The following extracts from the last report of the Chief of Engineers will indicate the present conditions of the work and results:

Southwest Pass was obstructed by a bar having 9 feet depth, and in the pass proper they reached to from 26 to 83 feet, mean low water. The existing project was adopted by the act of June 13, 1902, for a 35-foot depth and 1,000 feet in width, by dredging, two jetties to maintain the channel, the closure of all minor channels and removal of obstructions, sills, etc. The act also authorized the Secretary of War to modify the plans of 1900. Construction of jetties began December 31, 1903, and they were completed January 5, 1908, at a cost of $2,627,087.60. Total lengths about 37,000 feet. Cost, about $71.54 per foot. The dredge "Barnard," built at a cost of $240,000, reached

New Orleans September 3, 1904, and began work in the pass, April 21, 1905. Since that date dredging has been continued with the "Barnard," "Benyaurd," "St. Johns," "Sumter," and "Atlantic," and 8,131,256 cubic yards were removed up to June 30, 1911. Dredging was also done under contract in 1907 and 1908, when 3,574,318 yards were taken out and $466,035.31 paid the contractor. Sills were placed, outlets closed, buildings erected, machinery bought, and an additional dredge ordered, all of which have caused an expenditure of $5,620,276.88. Operations during the last fiscal year have resulted in the removal of 3,163,214 cubic yards by dredging.

On April 13, 1911, a contract was made for extending the east jetty 3,000 feet and the west jetty 3,750 feet and the building of two spur dikes. Ten spur dikes were built in connection with the jetties aggregating 7,240 feet in length. The available depth of channel is 31 feet at mean low water. The available depth in the South Pass at the same date was 29 feet.

"Any improvements in a stream like the Mississippi must be effected, both in time of execution and cost of operation, by conditions beyond human control."

Deductions.—The total prism of excavation since April, 1905, is 14,858,788 cubic yards, giving an average yearly removal of 2,409,528 cubic yards at an average cost of 6.33 cents per yard, instead of 4, as estimated, or nearly 60 per cent. higher. The estimated discharge of silt through this pass is 102,000,000 cubic yards, so that the dredges have handled only about 2 per cent. of the total, and, the outlets being closed, the residue must be discharged through the jetties, hence the rapid advance of over 3,000 feet in 7½ years since this project was begun. The normal rate was a half mile each decade. The ruling dimensions of the channel on June 30 were, depth 31 and width 360 feet. The spurs built during the year have aided in the deepening and indicate that the jetties are too far apart, and the groins are filling with sediment, as they should. It is manifest, therefore, that the jetties have hastened the advance of the bar and increased the deposits beyond them, while the channel is not self-maintaining. The east jetty has settled 1.6 feet and the west jetty 1.8 feet since being capped. The total appropriation has been $6,925,643.89, of which $5,620,276.72 is expended.

TAMPICO HARBOR AT MOUTH OF PANUCO RIVER, MEXICO.

(*Extract from "Shipping Illustrated" for February 18, 1911.*)

"The Mexican Government has made an appropriation of $10,000,000 to extend the jetties at the mouth of the Panuco River at Tampico, by which the present deep-water harbor is formed, farther into the sea for a distance of 700 feet and for dredging the bar at the mouth of the river. The stone breakwaters will be concreted on the sides and top and a walk constructed thereon."

The bar at the mouth of the Panuco River was about 4,400 feet off shore, and its depths varied from 5 to 12 feet with the seasons. It was improved by the construction of two straight, parallel, rip-rap jetties, of which the southerly one was 6,800 and the northerly one 6,500 feet long and 1,000 feet apart, capped with random stones weighing several tons, roughly placed from trestles, and afterwards maintained by derrick barges. The work was begun in March, 1890, and completed about the end of 1892, at a cost of $2,221,000 United States currency.

The fluvial discharge from the high plateaus is rapid and at its maximum reaches 215,000 cubic feet per second, having a velocity through the jettied channel of 7 feet per second and a slope of 10 inches per mile. The cross-section of the stream is 19,460 square feet. In heavy floods the ratio of sediment to water is 1 to 400, in ordinary stages it is 1 to 1,300, in bulk. There is a diurnal tide of 15 inches and a littoral drift to the southward, especially during the winter season. The flood of the summer of 1893 scoured out some 1,202,000 cubic yards, and the total removed amounted to about 4,000,000 cubic yards, resulting in a depth of 26.5 feet at mean low water, which was fairly well maintained by dredging at intervals.

On June 24 it was further reported as from the British Consul: "The condition of the harbor at Tampico leaves much to be desired in the way of dredging. The dredge is too small to keep the channel clear. The depth on the bar does not permit vessels drawing over 22½ feet to enter. The Government contemplates extending the jetties and their reconstruction, hoping to secure 30 feet."

The Tampico jetties, as well as those at the South Pass, were under the immediate construction of the world-renowned mari-

time engineer, Mr. Elmer L. Corthell, and are among the most satisfactory works of their class, both as to design and results, yet it would seem that even at the mouths of large streams bearing sediment they have their limitations and are not automatic and self-maintaining.

NOTES ON THE COLUMBIA BAR, OREGON.

(Data Compiled from Report of Chief of Engineers, 1911.)

In 1884 the first project was made for a half-tide jetty, 4½ miles long, on the south side, to be built of rubble stone deposited from a trestle. Temporary result, 31 feet, during readjustment of equilibrium. Cost, when raised to high tide with four groins added, was $1,968,753. Completed in 1895, followed by rapid shoaling, to arrest which the project was modified in 1903 by the proposed extension of the south jetty 2½ miles, the building of a north jetty, and by dredging. In 1901 the depths had shoaled to 21 feet and the channel had drifted some two miles to the northwest.

The estimated cost to secure 40 feet was $3,715,000. This project was again revised to raise the jetty to mid-tide level, in 1909, at a cost of $3,529,300, and to make it 25 feet wide at that level. In some places it is in 39-foot depths, thus "requiring an enormous increase in the amount of rock." Between September 20, 1910, and June 30, 1911, the dredge worked on the bar 62 days, removing 212,080 cubic yards of material. Project is 85 per cent. completed.

The survey of June shows the channel to have shifted about 2,500 feet to the northwest and that the depths vary from 25 to 27½ feet, an increase of 1 foot over last year. The mean tide is about 7.4 feet.

"The life of the trestle is very uncertain. . . . It is believed that the contraction of the entrance by the north jetty may be followed by scouring along the north side of the south jetty, and that for the maintenance of the south jetty two more groins should be provided, each about 500 feet long."

The total appropriations since June 13, 1902, aggregate $7,901,852.24.

From the above it appears that the actual gain in depth by jetty and dredging is about 5 feet, in some ten years, giving an average cost per foot of $1,580,370, and that the crest of the bar

is still two miles beyond the outer end of the extended jetty, while the channel is not fixed in position, but is still drifting rapidly northward, and the cut dredged has less depth than before it was begun. "The outer 24-foot contour has advanced some 3,000 feet since 1902, and the depths of 50 feet in that year had shoaled to 24 feet by 1909. On the southerly side of the jetty the 24-foot curve had advanced about 4,000 feet within two years, or about twice the length of the jetty extension in the same time, and large deposits had been made in the throat of the entrance between the jetty and Peacock Spit."

The proposed north jetty will merely arrest the northwardly moving littoral drift and cause more rapid advance of the bar, as has frequently happened elsewhere.

THE REACTION BREAKWATER.

As early as 1869, the writer, while stationed in Texas as United States engineer officer in charge of the district, began his investigations on these harbor questions, and after extended researches on snow-drifts, sand-dunes, and river currents, and also repeated surveys of shifting inlets, a system of works was evolved whereby a portion of a single, curved, resisting medium was so designed as to protect the bar-crossing from the resultant littoral drift, yet at the same time admitting the full tidal prism to the interior compartments, confining the effluent tides to a contracted path, and also causing a *reaction* by a constant change of direction, accompanied by scour and lateral transportation, and with no bar advance nor material interference with the prevailing littoral movements. By this means of connecting the deep water within and beyond the bar by a visible aid to navigation, under the lee of which there could be no shoaling because of the activities of the effluent waters, the current automatically constructed its own channel.

At Aransas Pass, Tex., the plan was tested on a practical scale by putting into position in twelve years instead of *one* a breakwater guaranteed to create a 20-foot channel across a bar of from 6 to 8 feet in depth.[2] The automatic channel has been secured by the feeble diurnal tide of 14 inches, at a cost of *less than one-fourth* of the amount estimated for the two-jetty channel. A ter-

[2] JOURNAL FRANKLIN INSTITUTE, February, 1908.

minal harbor is now being constructed with modern facilities for a commercial emporium on the Gulf for more than a million square miles of tributary territory.

The pass now has 23 feet of water 300 feet in width in the Gulf.[3] This is three feet more than the Government proposed to secure by two jetties with dredging at an estimated cost of $2,052,542, thus effecting a saving of over $1,616,078.

In other cases than the above, these methods are now being applied whereby bar and river channels are maintained automatically by the action of natural forces, and without recourse to constant dredging and stirring and other mechanical methods of removal.

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[3] *Shipping Illustrated,* February 3, 1912. See *Cassier's Magazine,* April, 1909, for paper on "Barriers to International Trade."